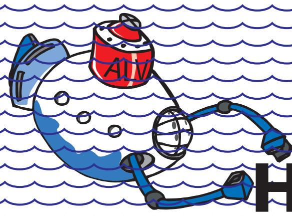

History's Thermometers

Focus
Paleoclimatological proxies

Grade Level
9-12 (Physics)

Focus Question
How can deep-water corals be used to determine long-term patterns of climate change?

Learning Objectives
Students will be able to explain the concept of paleoclimatological proxies.

Students will learn how oxygen isotope ratios are related to water temperature.

Students will be able to interpret data on oxygen isotope ratios to make inferences about climate and climate change in the geologic past.

Materials
- ❒ Copies of "Oxygen Isotope Ratios in Deep-water Coral Samples," enough for each student or student group

Audio/Visual Materials
None

Teaching Time
One 45-minute class period

Seating Arrangement
Classroom style, or groups of two or three students

Maximum Number of Students
No limit, if students work individually

Key Words
Paleoclimatological proxy
Isotope
$\delta^{18}O$
Deep-water coral

Background Information
Seamounts (also called guyots) are undersea mountains that rise from the ocean floor, often with heights of 3,000 m (10,000 ft) or more. Compared to the surrounding ocean waters, seamounts have high biological productivity, and provide habitats for a variety of plant, animal, and microbial species. Numerous seamounts have been discovered in the Gulf of Alaska. Many of these seamounts occur in long chains that parallel the west coast of the U.S. and Canada. One of the longest chains, known as the Axial-Cobb-Eikelberg-Patton chain, is being intensively studied by the Ocean Exploration 2002 Gulf of Alaska Expedition.

Several researchers on the Expedition are studying deep-sea corals. These animals have a hard skeleton like the familiar tropical reef corals, and often form branched shapes resembling trees or fans. Like their warm-water relatives, deep-sea corals form reefs and provide habitat to numerous other species. Besides being important to commercial fisheries, these corals are also of interest to scientists studying the Earth's long-term climate patterns. Deep-sea corals build their skeletons from calcium and carbonate ions which they extract from sea water. Oxygen and oxygen isotopes contained in the carbonate ions, as well as trace metals that are also incorporated into the corals' skeleton, can be used to determine the temperature of the water when the skeleton was formed. Because some corals live for many years (decades or even centuries), their skeletons contain a natural record of climate variability. Natural recorders are known as proxies, and include tree rings, fossil pollen, and ice cores in addition to corals.

When studying temperature records in proxies, we are usually interested in the ratio of the rare oxygen isotope ^{18}O to the common oxygen isotope ^{16}O. Because the absolute abundance of an isotope is difficult to measure with sufficient accuracy, the isotope ratios in a sample are compared with those in a standard, and the results are expressed as delta values, abbreviated $\delta(x)$ which is found by subtracting the isotopic ratio of the standard from the isotopic ratio of the sample, dividing the result by the ratio of the standard, and multiplying the 1,000 to give a result in parts-per-thousand (‰; also called "parts-per-mille"). Scientists have found that the ratio of oxygen isotopes in carbonate samples is inversely related to the water temperature at which the carbonates were formed, so high ratios of ^{18}O mean lower temperatures. In the simplest case, a temperature change of 4° C corresponds to a $\delta^{18}O$ of about 1‰.

Ocean temperature changes are known to have significant effects on climate and weather (e.g., El Niño), but these relationships are not generally well-understood. One of the first steps to improving our understanding of these interactions is to document variations that have occurred in the past. Comparing climatic conditions at different times in the past gives important information about rates of climate change. One of the major concerns associated with the prospect of global warming is that this climate change may be happening much more quickly than has been the case in the Earth's past. If this proves to be true, many organisms and living systems may have difficulty adapting to an unusually rapid rate of change.

Learning Procedure

1. Explain that seamounts are the remains of underwater volcanoes, and that they are islands of productivity compared to the surrounding environment. Point out that these undersea mountains can be quite steep, and provide unusual habitats for marine organisms. Discuss the deep-sea corals that are relatively common on seamounts, and be sure that students realize that these animals produce skeletons from calcium carbonate, and continue to grow and add to these skeletons throughout their lives. Explain the concept of climatological proxies, perhaps drawing an analogy to tree rings. Be certain that students understand the concept of isotopes, and explain that the ratio of oxygen isotopes varies with temperature. When oxygen, in both of its isotopic forms, is precipitated in the coral skeleton as calcium carbonate, a record is formed of the temperature at the time of precipitation. Be sure students understand that a temperature change of 4° C corresponds to a $\delta^{18}O$ of about 1‰.

2. Distribute copies of "Oxygen Isotope Ratios in Deepwater Coral Samples." Have students or student groups plot these ratios as a function of age ($\delta^{18}O$ on the y-axis). Ask students to explain their results. They should recognize that corals 1, 3, and 4 grew during a period in which water temperatures were relatively low (as would be the case during periods of glaciation), while corals 2 and 6 grew in warmer conditions. Coral 5 exhibits significantly different $\delta^{18}O$ in different portions of its skeleton. Have the students examine the data further to determine that the difference in $\delta^{18}O$ between two samples only 3 mm apart on the coral skeleton indicates that this coral experienced a rapid cooling of about 6° C in the space of less than 5 years. Discuss how this might have happened. Evidence for such an event has been reported, and has been interpreted to be linked to a rapid climate shift, the Younger Dryas cooling event which took place 13,000 to 11,7000 years ago. Discuss the significance of rapid versus gradual changes to biological communities.

The BRIDGE Connection

www.vims.edu/bridge - Go to Ocean Science Topics, then Ecology, then Corals for general information about corals.

The "Me" Connection

Have students write a paragraph on how global climate change would affect their personal lives.

Connections to Other Subjects

English/Language Arts, Chemistry, Mathematics, Biology

Evaluation

If individual evaluations are desired, have students write their interpretations of the data prior to the group discussion.

Extensions

Have students visit http://oceanexplorer.noaa.gov to keep up to date with the latest Gulf of Alaska Expedition discoveries.

Resources

http://oceanexplorer.noaa.gov – Follow the Gulf of Alaska Expedition daily as documentaries and discoveries are posted each day for your classroom use. A wealth of information can also be found at this site.

http://ethomas.web.wesleyan.edu/ees123/ – Very readable lecture notes on isotopes in paleoclimatology

http://www.ngdc.noaa.gov/paleo – NOAA site on paleoclimatology, with links to many other resources

http://www.sciencegems.com – Science education resources

http://www-sci.lib.uci.edu/HSG/Ref.html – References on just about everything

Smith, J. E., M. J. Risk, H. P. Schwarcz, and T. A. McConnaughey, 1997. Rapid climate change in the North Atlantic during the

Younger Dryas recorded by deep-sea corals. Nature 386:818-820. (The research paper on which this activity is based)

National Science Education Standards

Content Standard A: Science as Inquiry

- Abilities necessary to do scientific inquiry
- Understanding about scientific inquiry

Content Standard B: Physical Science

- Structure of atoms

Content Standard F: Science in Personal and Social Perspectives

- Natural and human-induced hazards

Student Handout
Oxygen Isotope Ratios in Deep-water Coral Samples

Coral Specimen	$\delta^{18}O$ (‰)	Age (years)
#1, base of coral	3.8	15,140
#1, 50 mm from base	3.9	
#1, 200 mm from base	4.5	
#1, 400 mm from base	4.1	15,550
#2, base of coral	0.8	3,100
#2, 70 mm from base	0.9	
#2, 220 mm from base	1.1	
#2, 450 mm from base	1.0	3,410
#3, base of coral	4.1	15,400
#3, 100 mm from base`	4.3	
#3, 200 mm from base	3.9	
#3, 300 mm from base	4.1	15,695
#4, base of coral	4.5	14,445
#4, 75 mm from base	4.1	
#4, 150 mm from base	3.9	
#4, 300 mm from base	4.0	14,800
#5, base of coral	1.7	13,300
#5, 80 mm from base	1.8	
#5, 85 mm from base	3.3	
#5, 100 mm from base	3.6	13,400
#6, base of coral	1.3	6,400
#6, 100 mm from base	1.5	
#6, 155 mm from base	1.6	
#6, 400 mm from base	1.4	6,675